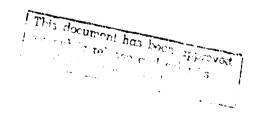COMPUTERS AND INFORMATION FLOW

R. L. Patrick

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COMPUTERS AND INFORMATION FLOW

R. L. Patrick[*]

Consultant to The RAND Corporation, Santa Monica, California

PREFACE

This Paper is a talk which is being given to inter-
ested audiences under a program established by University
of California Extension. It is aimed at the person who
has no knowledge whatsoever of the computing and data
processing field, but who has, or can expect to have, some
connection with it.

The lecture's purpose is to provide a general intro-
duction to the field, to pin down its unique terminology
and jargon, to identify the various types of computers and
the scope of computational capabilities, and to provide
some rules of thumb which can be applied in determining
whether a need for such a capability exists or not.

Although to date the audiences have been primarily
from the business world, the remarks should also be valu-
able to many others who have incidental contact with com-
puting, particularly in the military sphere and in educa-
tion. The Computer Sciences Department of RAND feels that
this Paper helps to fill the need for an easily understood
introduction to computing for the person who requires only
a layman's knowledge of the field.

COMPUTERS AND INFORMATION FLOW

The mathematics for astronomical computations, sci-
entific and engineering design, decision making, modeling
and simulation, and adequate project control, have, to a
greater or lesser degree, existed for many years. However,
the exploitation of these areas was hampered--although not
impeded--by the lack of a suitable device to rapidly and
economically manipulate them. In short, we did not have
an economic tool for the handling of these classes of
mathematics and their related data. Following World War II
the electronic computer made its debut. The first learned
paper which described its existence, as we know it now,
was published in 1946 by Von Neumann, Burk, and Goldstein.
In the short period of 22 years, a period shorter than the
time since some of you received your first college degree,
the computer has sprung from the gleam in the eye of a
recognized genius to a multi-billion dollar a year business.

The available time is too short to attempt to convert
you into computer experts. Instead, I shall try to intro-
duce you to the field, describe some of the constraints on
us and our operations, and then try and explain what all
of this means to YOU, whom we endeavor to serve.

A computer is a very expensive electronic-mechanical
device. In order to produce a device and write the engi-
neering costs off over a large production volume, the de-
vice must be designed to have broad appeal to a wide
variety of users. We call such a device a general-purpose
digital computer. A general-purpose device can be used
with practical efficiency across a broad spectrum of prob-
lems. To be sure, a specialized device will likely out-
perform a generalized computer, but, since it would have
limited appeal, the purchaser must be willing to bear all
of the development costs himself, as is true for any piece
of custom-designed equipment. About the only market for

intro

general-
purpose
digital
computer

special-purpose computers today is a very specialized
market, such as process control, or in-flight computers

special-purpose computer

where minimum weight dictates custom design. Thus, we find
we have two kinds of digital computers: the special-purpose
computer which is very efficient, custom-designed and ex-
pensive (relatively); and the general-purpose computer which
is less expensive and applicable to a broad range of problems.

In addition, there is another computer with which some
of you may be familiar, called the analog computer. One
kind of analog computer uses voltage levels to represent
quantities and performs its function by simulating (yes,
true simulation in every sense of the word) the physical
phenomena being considered. Thus, we may predict how the

analog computer

physical phenomena would respond to various stimuli. Analog
computers are excellent for simulation purposes and are
widely used. However, they suffer from accuracy limitations
and are also somewhat limited in the number of problems per
day which they can solve due to their set-up limitations.

Since the special-purpose computer must be integrally
designed into any system that one considers, and since the
analog computer is more or less limited in its applications,
the remainder of our attention will be directed towards the
general-purpose digital computer. The previous speakers in
this series have all dealt, more or less exclusively, with
general-purpose digital computers, although they may not
have been meticulously careful to make this clear. The
general-purpose digital computer is a compromise desi┐n
marketed by the computer manufacturer who endeavors to get
a broad market (and hence sales volume) for a single engi-
neering design and marketing effort.

digital

Furthermore, the word digital has a very special
meaning since information is represented internal to the
machine as numbers (and not by voltage amplitudes).

Each quantity retains its original accuracy and significance throughout the entire process. Thus, the general-purpose digital computer retains the accuracy commonly attributed to the bookkeeper while enjoying the dynamic range of problems usually considered by the engineer.

accuracy and significance

A digital computer is a tool used to process information. The advantages of computer processing of information over other modes of processing are increased accuracy and compression of elapsed time. The classical organization of computer hardware dictates that each information processing task be sub-divided into three major functions: input, compute, and output.

computer is a tool

These three basic functions can be implemented in a variety of ways depending on the requirements of the processing task. Input information is usually contained on some combination of the following media: 80-column punched cards, punched paper tape, magnetic tape, teletypewriter lines, or special instrumentations such as azimuth or elevation readouts of a radar. The information contained on such input media is made available to the computer by a variety of input devices, such as 80-column card readers, punched paper tape readers, magnetic tape transports, or buffer and control circuitry required by special instrumentation devices.

input

After processing, the information may be output from the computer onto one of several recording media. These media are: printed pages from a high-speed printer (hard copy), 80-column punched cards for subsequent processing, magnetic tape for either immediate or delayed re-use, automatic messages prepared for direct entry into a communications network, or a control signal into a myriad of special-purpose action devices. Depending upon the requirements of the processing task, a system designer may choose from such readily available output devices as line printers, card punches, magnetic tape transports, and punched paper tape

output

devices. Or he may select special-purpose gear to meet
his unique requirements.

compute　　　　The compute function is performed on a highly inte-
grated device having two primary parts: 1) a store; 2) an
arithmetic and control unit. A large high-speed core store
receives information from the input units, retains inter-
mediate products of computation, and builds up the final
output.

For the class of general-purpose machines to be dis-
cussed here, this store is also used to retain a coded
version of the processing procedure. This form of computer
organization is credited to Von Neumann; the scheme is called
stored
program-
ming
stored programming. Currently, the primary constituents of
a large store are magnetic cores. Core storage usually has
a uniform rapid access to any information stored within it
and a relatively high unit cost per quantity of information
stored. The input-output devices and core storage are
governed by the arithmetic-control unit. The circuitry
associated with this control unit controls the reading of
new information, the access to information in core storage,
and the recording (on an output device) of processed in-
formation. In addition, the arithmetic-control unit con-
tains special circuitry for the usual arithmetic operations
(add, subtract, multiply, and divide); the logical opera-
tions (fetching information from core storage, recording
information in core storage, and comparing two items of
information); and simple decision processes (e.g., testing
the algebraic sign of a quantity and, on the basis of this
test, taking one of two alternate computational paths).

An additional type of hardware is often incorporated
into the above organization. The core device   a rela-
tively expensive way to obtain storage capacity. For this
reason core storages are usually constructed large enough
to contain only information frequently used. Information
auxiliary
storage
which is occasionally used is retained on auxiliary storage
devices.

Frequent examples of auxiliary storage are such mag-
netic media as magnetic tape units, magnetic drums, or
magnetic discs. They can store information semi-permanently
and retain such information for extended periods of time.
Magnetic tapes are serial in character and can be removed   tapes
from the computer and shipped or stored. Magnetic drums   drums
are intermediate in capacity and retain information as
magnetized spots on a metal cylinder that rotates at con-
stant speed. Therefore, information is available to the
computer in a cyclic fashion.

In an effort to overcome the capacity limitations of
a magnetic drum while still retaining the cyclic feature,
magnetic discs were developed. The surface area available discs
for recording has been greatly increased by mounting
several large discs on one single shaft and rotating the
shaft at constant speed. Discs have the cyclic character-
istic common to magnetic drums. Some magnetic discs are
removable and can be shipped and stored like tapes.

The last three mentioned devices--magnetic tapes,
drums, and discs--are termed secondary storage; core de-
vices are termed primary storage. Primary storage is that
storage which is most closely associated with the arith-
metic and control unit. Secondary storage appears to the
computer as an input-output unit. Although the time re-
quired to obtain a specific item of information from any
secondary storage unit is considerably higher than the
time required to obtain a similar item from core storage,
the cost of secondary storage is significantly less than
the per unit cost of core storage.

Two terms, common to the computer field, are almost
self-explanatory yet cause some confusion among managers.
These two terms are hardware and software. The defini-   hardware
tion of hardware is fairly well accepted; I quote from   and
                                                            software
the latest Federal glossary, "hardware: the physical
equipment or devices forming a computer and peripheral

equipment. Contrasted with software." Thus, the devices we have discussed are hardware.

A general-purpose digital computer, as it is delivered by the manufacturer, is incapable of performing any useful function. As was mentioned before, "this store is also used to retain a coded version of the processing procedure." The statement could even be made stronger: the store must be used in this manner or useful work cannot result. This coded version of the processing procedure we call a computer
computer program
program. It is the result of a series of meticulous steps by a human programmer and, once completed and checked out, adapts this general-purpose device to a specific task.

The computer itself has been harnassed to aid programmers in the preparation of applications programs. This is a form of bootstrapping: they use the computer to help prepare other computer programs. The programs which perform this assistance are called software. These are programming aids supplied by the manufacturer to assist programmers in the preparation of applications programs.

In the early days of the field these programming aids were produced locally by each individual installation. We finally decided to moderate our requirements somewhat and the manufacturer produces these once for all the users of a given line of equipment. He graciously adds a little bit to the bill each month to cover their cost. I quote again
software
from the same Federal glossary, "software, the totality of programs and routines used to extend the capabilities of computers, such as compilers, assemblers, narrators, routines, and sub-programs. Contrasted with hardware."

Thus we are beginning to get a view of a computer service center. Generally, the computer service center does not directly produce a saleable product, but merely exists to assist other operating units of the organization. In the performance of this function, it is a service center in every sense of the word, just as accounting, drafting,

and housekeeping are service functions. They are all required, but contribute indirectly to the profitability of the business.

Before we proceed on our own computer center there are one or two major considerations which should be understood. Since the computer industry is changing so rapidly, most of the computers in the field today are rented. The manufacturer takes the risk of obsolescence and the user invests his risk capital elsewhere. The monthly rental for a computer covers the rent for the machine, its maintenance, and spare parts. In a field changing as rapidly as ours, the purchase price of a machine is usually 40 to 50 times rental.

rental agree- ments

For your basic rental dollar you require such a machine for only 176 hours per month. This is called basic single-shift usage, and is roughly equivalent to eight hours a day five days a week. If you require more computing capacity than single-shift, an additional use charge is assessed. Typically, this charge is only 10 percent of the first shift hourly cost. Thus, you have a full two-shift operation for only 110 percent of the basic rental agreement. Similarly, three-shift operation costs only 120 percent of the basic rental rate. The manufacturers thereby encourage a smaller manufacturing volume and a faster write-off on the volume produced. This, in turn, affects the attitude of the installation manager and his relationships with his customers. The installation manager is sitting on top of a huge capital investment and he is inclined to exploit it on a multi-shift basis.

With some obvious exceptions, a good rule of thumb for the total cost of such an installation is to double the basic machine rental. A computer can run from about a $1000 a month rent (small), through the medium price range ($20,000), up to the large processor which rents for approximately $80,000 per month. A single shop which

total cost

consists of one IBM System/360 Model 65 (at $65,000 per month rent), ancillary computers for handling input-output functions, the programming staff, and the related overhead would cost approximately $130,000 per month, or $1,560,000 per year. If we only ran this machine single-shift, the total cost per hour operation would be $740 per hour!

This accounts for another peculiar whim common to installation managers. They are highly efficiency-oriented. They get this way and stay this way due to frequent budgetary reviews and checks by higher management. In many cases the computer facility is the largest single line item in a corporation budget. Therefore, the budgeteers appear more frequently at our doors to make sure that we are spending our sums properly.

large budget item

As we mentioned earlier, programmers are an integral part of the program preparation process. They meet with customers, extract problem statements from them, muse over these problem statements, return for more information, program the process for the machine, check it out, run some pre-production test cases, and proceed to work out the deficiencies with the customer. As a byproduct of this they document the procedure. A useful byproduct of this documentation is a problem statement, available to the customer, perhaps for the first time.

program-
mers

The programming field (and the computer field as a whole for that matter) has grown up like Topsy. We're the products of our environment rather than the result of a concerted training and education program. There are some indications that this is beginning to change, but, at the present time, programmers are both the biggest boon and the biggest problem to an installation manager. We're usually overpaid for our experience and education and sometimes inclined a little towards the prima donna. We are faced with huge responsibilities and in many cases work with little or no direct supervision. These things are all

program-
ning
field

frustrating, to say the least. Some of you who have been or soon will be directly associated with the computer operation will experience some of this frustration. You too do not have the proper background to communicate properly with a programmer (your attendance at this forum is a certain admission of that fact) and he probably similarly lacks the requisite knowledge of your specialty. Through seminars and symposiums such as this we will gradually break down this communication barrier and improve operations by educating both parties to the discussions.

communication barrier

Much earlier we stated that "the advantage of computer processing of information over other modes of processing are increased accuracy and compression of elapsed time." Since time is usually equated to money, we could have added "lower costs," but, while this is usually true, it is not always. It seems appropriate to point out some classifications of computer applications which we have found to be useful. There are seven of these. The first one is somewhat a misnomer but persists in the field, hence we must discuss it. This is the so-called scientific computer application.

advantages of computer processing

The term originated since many of the early computer applications grew from the fields of science and engineering. These applications have the characteristics of relatively little input and output and a high volume of arithmetical computations which are liberally sprinkled with multiplications and divisions. Another term, also somewhat of a misnomer, is the business application. This term was generated by the early predominence of accounting applications which were characterized by extremely high volumes of input and output, little computation, and rather simple decision processes.

scientific application

business application

Although these two terms are traditional within the field, they are gradually beginning to lose their original

significance since many of our modern scientific and engi-
neering applications have heavy compute and heavy I/O
(input/output). Furthermore, our business applications
are tending more towards t'e integrated data processing
application wherein the total processing per unit of in-
put data is greatly increased. Thus, these two areas are
gradually growing together.

Another pair of terms very much in data processing
literature today are batch and on-line. These two ad-
jectives are used to modify the noun "process." With
batch processing we gather our transactions into economical
groups called a batch. We then treat the entire batch as
batch   a unit and process it with a computer. This is no more
process   nor less than an adaptation of popular techniques in both
accounting and manufacturing. If one does not have enough
accounts-payable to occupy a clerk full time, the accounts-
payable are allowed to accumulate for a reasonable period
and then one clerk is assigned to clean up this small back-
log. In a similar way if one had some sort of an auto-
matic machine tool, such as a turret lathe, the setup costs
would be high. We would schedule fairly long production
runs based on the same setup to use the machine effectively.
The computer operations manager has adopted this technique
for the same reasons.

on-line   On the other hand, on-line processing was developed
process   by the field in response to customer's demand for time
currency. Some applications (not in the majority by any
means) profit materially from management knowledge of the
instantaneous status of things. This dictates that trans-
actions be processed as they are received rather than
collecting them and batch processing them. As you might
imagine, the entire organization must be tuned to such
processing. The first applications in this area were in
fire control and missile guidance. More recently, several
non-defense applications have resulted, one of the more

popular being on-line manufacturing scheduling, such as
is performed in the Lockheed-Burbank plant.

In manufacturing a large complex assembly, a workable
schedule is first designed. Once such a schedule has been
adopted, management is intimately concerned in any devia-
tions from the schedule. Their first concern is, "Can I
get it back on the original schedule?" Their second con-
cern is, "O.K., if one part is going to be late, can I
use this extra time to increase my profits by adjusting
some related schedules?"

A special example of the on-line operation is the
real-time operation. Before we discuss real-time, we
should sharpen our definition of on-line a bit.

A computer is frequently said to operate on-line.   on-line
Where human frailities require the support of a computer
in a line position (juxtaposed to a staff position), the
computer is said to be on-line.

Frequently, people can conceive and design situations
which are beyond the scope of human capabilities. These
may involve some combination of extremely high accuracy,
voluminous data, or extremely (relatively) short response
time. One solution to such a dilemma is to install a
computer on-line. In this type of operation the computer
must operate as reliably and flexibly as its human counter-
parts. Sometimes special consoles, special hardware, and/
or direct communication lines are associated with this type
of operation. If time is not critical, on-line operation
does not preclude batch processing.

Occasionally, a computer exists on-line in an un-   real-time
forgiving environment, which is not and cannot be made
subservient to computer control. Usually a physical pro-
cess is involved. If the time available for solution is
only slightly larger than the time required for computa-
tion, the environment is said to be real-time.

The aforementioned cases of fire control and missile guidance were examples of real-time computer applications. Other examples are telephone switching, and the control of traffic signals.

One type of on-line operation occurs with sufficient frequency to be mentioned here. It is an application known as process control. The process control field is about equally populated with special-purpose computers and with general-purpose computers. In process control the applica-tins are rather specialized, the computer is used on-line in a control capacity, and the resultant process is actually under control of action devices stimulated by the computer's outputs.

process
control

The control of large alternators is one such applica-tions area. Several large steam-turbine-driven generators are placed under the control of one computer. The computer keeps track of the consumption on the line and matches the generator's output to the needs of the consumers. This is done by bringing generators up to speed, synchronizing them with the line, and placing them on the line to carry a por-tion of the load. The generators so ganged then have their outputs adjusted throughout their part-load range to minimiz᠎ their operating costs while satisfying the consumer demand. This is an on-line real-time computer application.

Another example is at Standard-El Segundo where a portion of the refinery is being dynamically control᠎d by an on-line digital computer. Similarly, an on-line device is controlling the output of a cement plant in Riverside to minimize the amount of unusable ᠎aste produced by the kiln.

A special type of on-line process is called command and control. This is usual᠎ᵛ characterized by the sheer magnitude of the task, the complexity of its solution, and of the amount of Federal funds expended in its pursuit. You may have heard of the large Air Force "L" systems which

command
and
control

a rather frequently in the news. These are command and control systems. The most widely known of these is the SAGE system which is a large nation-wide air defense system. It receives its basic data from communication lines attached to search radars and has as its primary output displays to human control officers. These displays, if accepted, become automatic output messages to defensive armements.

Earlier it was said that this session would help YOU. Perhaps the best way to accomplish that is to supply you with the five symptoms that usually accompany a latent computer application.

five symptoms

1) Any <u>volume operation</u> where the processing can be defined. It is not necessary to define all processing. It must be possible to define the repetitive portion and be able to describe the exceptions in order that the computer can select the exceptions for human action. This is clearly the predominent characteristic of most of our large business data processing, manufacturing scheduling, accounting, labor distribution, payroll, and inventory control applications. The required processing per item is usually not severe, but the sheer volume of items to be processed makes it economical to tool up and perform this processing on a computer.

volume operation

2) Any <u>extremely complex job</u> is a candidate. It is not necessary for a job to occur in volume if it is complex enough. Some things have so many separate steps that people just cannot concentrate for a sufficient period to perform them adequately.

complex job

The complexity factor is usually prevalent in most of our so-called scientific or engineering tasks. True, we did accomplish them in earlier years with tables and computresses, but we were required to make rather astute engineering judgments to simplify the calculations involved. The full-blown calculations were too formidable to contemplate

by hand. Some of you may remember when we had a very com-
plex job that just had to be right, we restricted ourselves
to only a few data points, set two computresses to the task,
and they performed in parallel. Only in this way could we
have any confidence that the results were correct. Compare
this with today when a programmer performs the task once
for all and the computress performs a single-hand computa-
tion which is sufficient for all. Then our computers,
large willing slaves, unerringly and without complaint pro-
duce all the answers you are willing to pay for.

payoff
function

     3) Another latent computer application is any job
where the payoff function varies drastically with time.
Any time the marginal value of a computer solution starts
out at a very high dollar value for immediate solution and
goes to zero for an historical solution, a computer applica-
tion may be forthcoming. Furthermore, the time constraint
may cause the application to be on-line or even real-time.

     There are many present examples of this phenomenon among
the military. Missile guidance, the processing associated
with early warning, range safety, and fire control are but
a few examples. To a lesser degree there are applications
among civilian endeavors. Scheduling is frequently of this
nature. From the time inventory reports come in from the
field, the information for a new schedule is available. If
the new schedule differs quite drastically from the old,
then haste is of the essence, for the manufacturing fa-
cility is, in the intervening period, building for inventory
and not for sale. This, of course, is the motivation behind
PERT and similar management control techniques. In the not-
too-distant future we might find the dispatching of fire and
other emergency vehicles placed under computer control for
this reason. Furthermore, there is some glimmer of hope
that information retrieval for medical purposes will be
automated, since the value of timely current information

to the examining doctor is, in many cases, a matter of life and death.

    4) Another computer application comes about any time a <u>large file</u> is involved and it is further necessary that this file be <u>curren</u> and <u>accessible</u> by <u>several</u> users at the same time. Clearly, one way to have a file current is to have only one copy of that file. In addition, a computerized file can answer several requests simultaneously even if they reference the same portion of the store.

    large file

The most common example of large files in the civil domain is inventory control. Many firms have found it expeditious to automate their files to avoid over-selling fast-moving items and tying up their inventory dollar in snails. One way to achieve customer happiness is to increase the size of the inventory. While this increases customer happiness and sales temporarily, the investment in inventory may be so huge that the firm fails to turn a profit and dies.

    Another approach to this is to centralize the control of the inventory (not necessarily the physical location of the stocks), and to cause a computer to process all transactions against the file and perform the companion operations of invoicing and reordering. Quite often the savings in reduced inventory levels on the slow-moving items more than pay for the cost of the computer operation.

    5) A fifth way to recognize a computer application is to find a job, any job, not necessarily large and voluminous, where <u>sterile</u> handling is of the essence.

    sterile handling

This kind of an application would be characterized by extremely precious data. Examples of this would be in the control of classified documents within an engineering department or, in the civil domain, in the banking industry where postings are equivalent to dollar values.

Thus, you have been introduced to some of the more important terms of the computer field. You have been allowed to peek behind the scenes to see how we operate and that we have problems too. Furthermore, you have been supplied with handy rules of thumb which will allow you to detect a latent computer application in the event you might stumble upon one.

closing   In closing, allow me to chasten you a little bit. Such a brief introduction cannot hope to make computer experts out of you. If you think you've come across a computer application, two courses are open to you. You may pursue the course which I have taken and eventually become a computer specialist yourself. Or, you may seek out some present practitioner (either in-house or out) and request his advice or counsel.